TWO-DIMENSIONAL WATER QUALITY MODELING USING CE-QUAL-W2 ON SELECTED RESERVOIRS

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REFERENCE: Proceedings of the 1999 Georgia Water Resources Conference, held March 30-31, 1999, at The University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Detailed modeling studies of major reservoirs within the ACT and ACF River basins were conducted to provide a basis for comparison of the impact of alternative allocations on the water quality of the reservoirs. The hydrodynamic and water quality model CE-QUAL-W2 was applied to six reservoirs within the ACT/ACF. The reservoirs included: West Point and Walter F. George (Lake Eufaula) Reservoirs on the middle and lower Chattahoochee River between Georgia and Alabama; Weiss Lake and Lake Neely Henry on the Coosa River in northeast Alabama; and Lake Allatoona and Lake Lanier in northern Georgia on the Etowah and upper Chattahoochee Rivers, respectively. The inflows, and their associated temperatures and water quality concentrations, and outflows for the CE-QUAL-W2 applications for each reservoir were provided from the results of the application of HEC-5Q to the two basins. Simulations were conducted first to establish the baseline conditions for comparison, the no action alternative, which will be followed by simulations of the action alternative, based upon the water allocation formula.

DESCRIPTION OF MODEL

CE-QUAL-W2 (W2, Corps of Engineers, Quality Model for two dimensional waterbodies) is a two-dimensional, laterally averaged hydrodynamic and water quality model, supported by the U.S. Army Engineer Waterways Experiment Station (CEWES, Cole and Buchack 1995). W2 predicts variations in water movement, temperature, and constituents longitudinally and vertically. Lateral variations are assumed to be minor, compared to longitudinal and vertical variations, so that an average water quality across the width of the reservoir is assumed. This is generally a valid assumption in reservoir systems.

W2 is based upon a finite difference solution of the laterally-averaged equations of fluid motion including: the free water surface, hydrostatic pressure, horizontal momentum, continuity, constituent transport, and an equation of state relating density and constituents, including temperature and solids concentrations. In addition to temperature, up to twenty-one water quality constituents can be simulated, and the model can be run at varying levels of complexity. The constituents simulated in this study are included in Table 1.

W2 predicts values for hydraulic parameters and the water quality state variables simulated for each model segment and at each model time step, and for the reservoir outflows. In addition to the predicted values, the model also computes certain derived variables, such as chlorophyll-a concentrations from the computed internal biomass units. As part of this application, the methods for the presentation of model results were designed by the ACT/ACF study partners to best accommodate their needs for assessing the relative impact of changing conditions between the action and no-action scenarios. The code was modified to compute water age, equivalent to the residence time, using methods developed by CEWES. The code was also modified to average and output certain quantities over the reservoir and its photic zone and aphotic zone based upon using computed light extinction coefficients. A post-processor was developed to enhance the graphical presentation of the results. X-Y plots and animated contour plots were developed to further demonstrate output results.

Table 1.
CE-QUAL-W2 Constituents Simulated in this Study.

- Water temperature
- Inorganic suspended solids (Lake Lanier only)
- Water age
- Labile DOM
- Refractory DOM
- Algae
- Detritus
- Phosphorus
- Nitrate-nitrite
- Ammonium
- Dissolved oxygen
- Sediment (selected reservoirs)
- Iron (Lake Lanier only)
- Manganese (Lake Lanier only)

MODEL APPLICATION

The application was based on existing, calibrated, W2 models for each of the six reservoirs. The CEWES developed W2 models for Weiss, Neely Henry, and Walter F. George Reservoirs as part of the ACT/ACF Comprehensive Basin Water Resources Study. Additionally, CEWES completed applications to Allatoona and West Point Reservoirs as part of a study for the Georgia Department of Natural Resources through an agreement with the U.S. Army Engineer District, Mobile (CESAM). The W2 model was applied to Lake Lanier by Limno-Tech, Inc., through a study for the Upper Chattahoochee Basin Group, comprised of county and municipal governments in the area around Lake Lanier. The objective of this study was to, using the calibrated W2 models and results of the HEC-5Q water quality modeling studies, evaluate the potential impact of a range of flows from the allocation formula on the water quality of six reservoirs in the ACT and ACF basins, relative to the no action alternative.

The input to the W2 applications was based upon the application of the HEC-5Q model to the two basins. The HEC-5Q model, developed by the Corps Hydrologic Engineering Center (CEWRC-HEC), was applied to the two basins by Resource Management Associates (RMA) and the Corps of Engineers Hydrologic Engineering Center (CEWRC-HEC), under contract to CESAM. HEC-5Q simulates the sequential operation of reservoir systems for flood control and conservation purposes, including water quantity and quality. HEC-5Q is a direct expansion of the water quantity portion of the HEC-5 program used in the flow simulations of the two basins by CESAM.

HEC-5Q is one of three predictive models applied to the two basins as part of the impact assessment: (1) A basin wide one-dimensional water quality model (HEC-5) to evaluate stream and reservoir water quantity throughout the basins; (2) a nonpoint source model, Better Assessment Science Integrating Point and Nonpoint Source (BASINS), which predicts the non-point source loadings for input to the HEC-5Q model; and (3) a basin-wide one-dimensional water quality model (HEC-5Q) to evaluate stream and reservoir water quality throughout the basins. The HEC-5Q simulations integrated the flow output data predictions from the HEC-5 model, the non-point source loading predictions from EPA's BASINS, predictions developed by EPA for point source loadings, and field data from the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA). The HEC-5Q model was applied to predict flow and water quality data throughout the two basins for the action and no action alternatives. The predictions at node locations corresponding to inflow locations and reservoir outflows were obtained from RMA and processed to create input for the W2 applications. The W2 applications were developed to provide for a more detailed comparison of the water quality impacts of the alternatives in the six selected reservoirs in the ACT and ACF.

EVALUATION OF NO ACTION ALTERNATIVE

The W2 simulations were conducted for the no action alternative. The no action alternative is the baseline condition against which the future action alternative flow scenarios will be compared. The no action alternative assumes that existing project operations will continue unchanged into the future. The no action alternative was developed for the present condition (1995), and two future conditions (2020 and 2050). The no action alternative was based upon current water use patterns, taking into account baseline (1995) water supply demands and increasing water supply demands for the future (2020 and 2050. Although the HEC-5Q model was run for a period of five years using meteorological data for the period of 1984 to 1988 for each of these conditions, the W2 simulations were limited to a single year of simulation. The meteorological conditions for 1986 were selected by the ACT and ACF study partners as the critical conditions for the W2 simulations. The calibrated W2 models were applied to each of these conditions, and to each reservoir, using boundary conditions from the HEC-5Q simulations and the results compiled. Once an allocation formula is identified, it will be modeled using W2 so that the resultant impacts can be compared against the no action alternative.

REFERENCES

Cole, T.M. and E.M. Buchak, 1995. "CE-QUAL-W2: A Numerical Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 2.0 User Manual", Instruction Report EL-95-1-, US Army Engineer Waterways Experiment Station, Vicksburg, MS.